predetermined value. As a result, the optical modulating unit 11 operates normally as a modulating unit because it does not receive a signal from the modulation controlling unit 65.

[0155] Note that, the controlling unit 14 controlled by the optical communication apparatus according to the input light of the optical modulating unit 11 as shown in FIG.13 can also be controlled according to the output light of the optical modulating unit 11 or a modulation signal as shown with broken lines.

[0156] Next, the optical communication apparatus according to the fourteenth embodiment will be explained based on the accompanying figure.

[0157] As shown in FIG. 14, this optical add/drop apparatus is composed of an add/drop unit 70, an optical wavelength branching unit 73, and an optical adding unit 75.

[0158] Actually, the optical add/drop apparatus is provided with optical wavelength branching unit 73 and optical adding unit 75 in the number equivalent to the number of wavelengths of light beams to be added or dropped. However, each optical wavelength branching unit 73 is the same in configuration and different only in the wavelength of light on which to perform a receiving operation, and each optical adding unit 75 is the same in configuration and different only in the wavelength of light to be added. Therefore, in FIG. 14, only one of the plurality of optical wavelength branching unit 73 and only one of the plurality of optical adding unit 75 are shown by solid lines and the other unit are shown with broken lines.

[0159] The add/drop unit 70 is connected to an optical transmission line for transmitting through a wavelength-division multiplexed optical signal, and adds and drops optical signals of at least one wavelength to and from an optical signal transmitting through the optical transmission line. When dropping, optical signals are dropped to optical wavelength branching unit 73 via an optical distributing unit 72 that distributes optical signals in accordance with the number of optical wavelength branching unit 73. When adding, an optical multiplexing unit 74 multiplexes adding optical signals coming from respective optical adding unit 75 wavelength-division multiplexes the multiplexed addition light with an optical signal trajecting the optical add/drop apparatus and outputted to the optical transmission line.

[0160] The optical wavelength branching unit 73 performs receiving operations on distributed optical signals of respective wavelengths. On the other hand, the optical adding unit 75 generates addition light beams to be added to an optical signal on the optical transmission line.

[0161] The configuration of each optical adding unit 75 will be described below, which is composed of optical branching unit 10 and 12, an optical modulating unit 11, an operating point controlling unit 13, a controlling unit 14, and an optical detecting unit 15.

[0162] Input light of a particular wavelength that is entered to an input port is branched by the optical branching unit 10. First branched input light that has been branched off by the optical branching unit 10 is modulated by the optical modulating unit 11. A modulated optical signal is branched by the optical branching unit 12. Each particular wavelength is different among the respective optical adding unit 75.

[0163] The first optical signal branched off by the optical branching unit 12 is exit to an output port and entered to the optical multiplexing unit 74. On the other hand, the second optical signal branched off by the optical branching unit 12 is entered to the operating point controlling unit 13 that controls the operating point of the optical modulating unit 11.

[0164] On the other hand, the optical detecting unit 15 detects the intensity of second branched input light that has been branched off by the optical branching unit 10, and outputs a signal in accordance with the detected light intensity, which is inputted to the controlling unit 14.

[0165] In this manner, the optical detecting unit 15 can detect whether the intensity of input light is a predetermined value or less. Therefore, when the intensity of the input light is the predetermined value or less, the controlling unit 14 can control, in accordance with the output of the optical detecting unit 15, the operating point controlling unit 13 so that it can keep the operating point stable. As a result, in the optical add/drop apparatus having the above configuration, the operating point of the optical adding unit 75 can be kept stable even when the optical adding unit 75 has no input light because no addition light is to be supplied to the add/drop unit 70.

[0166] Naturally, the optical detecting unit 15 does not output any signals when the intensity of input light is larger than the predetermined value to generate addition light by the optical adding unit 75. Therefore, the operating point controlling unit 13 controls the operating point to the optimum value only based on the output of the optical modulating unit 11 that is entered via the optical branching unit 12.

[0167] Note that, the optical communication apparatus according to the first embodiment applied as optical adding unit 75 in the fourteenth embodiment can be replaced by the optical communication apparatuses in the second through the thirteenth embodiments.

[0168] Next, the fifteenth embodiment will be explained.

[0169] First, the configuration of the fifteenth embodiment will be described.

[0170] In FIG. 15,this optical add/drop apparatus is composed of optical amplifiers 101 and 103, an OADM 102, an 1 x M optical coupler 104, M optical wavelength branching circuits 105, an N x 1 optical multi/demultiplexer 106, and N optical addition circuits 107a.

[0171] Although this optical add/drop apparatus has the M optical wavelength branching circuits 105 and the N optical addition circuits 107a, in FIG. 15 only one of

the M optical wavelength branching circuits 105 and only one of the N optical addition circuits 107a are shown by solid lines and the other circuits are shown with broken lines because the circuits of each group have the same configuration.

[0172] A wavelength-division multiplexed optical signal transmitting through an optical transmission line enters the optical add/drop apparatus and is amplified by the amplifier 101 that amplifies an optical signal to predetermined light intensity. The amplified optical signal is entered to the OADM 102 that adds or drops a wavelength-division multiplexed optical signal. Signal light beams of predetermined wavelengths that have been dropped by the OADM 102 are entered to the 1 x M optical coupler 104 that divides the optical signal(s) into as many optical wavelength branching circuits there are. The optical signal(s) distributed by the 1 x M optical coupler 104 are entered to and performed receiving operations on optical signals of respective wavelengths in the optical wavelength branching circuits 105. On the other hand, optical signals to be added in the OADM 102 are generated by the optical addition circuits 107a, which are provided in N, that is, the number of optical signals to be added in the OADM 102. The optical signals to be added and an optical signal that has not been dropped in the OADM 102 are wavelength-division multiplexed with each other, and a resulting optical signal is amplified by the optical amplifier 103 and then outputted to the optical transmission line.

[0173] Each optical addition circuit 107a is composed of a laser diode bank (hereinafter abbreviated as "LD bank") 110, optical amplifiers 111 and 115, optical couplers 112 and 114, an MZ modulator 113, PDs 116 and 123, amplifiers 117 and 121, a comparator 118, a switch 119, a variable gain amplifier 120, a coupling capacitor 122, a buffer amplifier 124, a multiplier 125, an LPF 126, a differential amplifier 127, an inductor 128, a capacitor 129, a resistor 130, and a low-frequency oscillator 131.

[0174] The circuit composed of the variable gain amplifier 120, the amplifier 121, the coupling capacitor 122, the PD 123, the buffer amplifier 124, the multiplier 125, the LPF 126, the differential amplifier 127, the inductor 128, the capacitor 129, the resistor 130, and the low-frequency oscillator 131 is called an operating point control circuit.

[0175] In FIG. 15, the LD bank 110 can exit laser beams of a plurality of wavelengths L1-L8 corresponding to the wavelengths for wavelength-division multiplexing. The wavelength of light to be exited actually is selected in accordance with a detection signal that is generated by detecting available wavelengths of the optical transmission line with a wavelength monitor (not shown in FIG. 15). For example, the LD bank 110 exits light of a wavelength L2, which is entered to the optical amplifier 111. Amplified light is branched into two beams by the optical coupler 112, and first branched light is entered to the MZ modulator 113.

[0176] A modulation signal and a low-frequency signal of a predetermined frequency f0 that is outputted from th low-frequency oscillator 131 are inputted to the variable gain amplifier 120. The variable gain amplifier 120 amplitude-modulates and outputs the signal received. The output signal is inputted to one modulation-input terminal of the MZ modulator 113 via the amplifier 121 which gains a predetermined signal level and the coupling capacitor 122.

[0177] The resistor 130 and a bias T circuit that is composed of the inductor 128 and the capacitor 129 are connected to the other modulation-input terminal of the MZ modulator 113.

[0178] The MZ modulator 113 modulates the light of the wavelength L2 that is exit from the LD bank 110 into an optical signal with the signal supplied from the drive circuit and outputs it.

[0179] Part of the output light of the MZ modulator 113 is branched off by the optical coupler 114 and thereby taken out. The other part of the output light is amplified by the optical amplifier 115 and then entered to the above-mentioned N x 1 optical multi/demultiplexer 106. The branched part of the output light is detected by the PD 123. A detection signal is amplified by the buffer amplifier 124 that selectively amplifies a frequency component of f0, and is inputted to the multiplier 125. The low-frequency signal that is outputted from the low-frequency oscillator 131 is also inputted to the multiplier 125. The multiplier 125 compares the phases of the input signal supplied from the buffer amplifier 124 and the low-frequency signal supplied from the low-frequency oscillator 131, and outputs a signal in accordance with a phase difference. The multiplexer 125 detects the low-frequency signal of the predetermined frequency f0 that was superimposed by the variable gain amplifier 120.

[0180] The output signal of the multiplier 125 is inputted to one input terminal of the differential amplifier 127 via the LPF 126 that allows passage of a frequency component of the predetermined frequency f0 or less and the switch 119. The other input terminal of the differential amplifier 127 is grounded. An output of the differential amplifier 127 is inputted to the inductor 128 of the bias T circuit as an error signal to be used for moving the operating point, and the bias value is variably controlled so as to correct the operating point.

[0181] On the other hand, second branched light that has been branched off by the optical coupler 112 is entered to the PD 116, which outputs an electrical signal that is in proportion to the average intensity of the second branched light. That is, the PD 116 detects the intensity of the light that is exit from the LD bank 110.

[0182] The electrical signal that is outputted from the PD 116 is amplified by the amplifier 117 and then compared with a reference voltage Vref by the comparator 118. When the electrical signal is smaller than or equal to the reference voltage Vref, the comparator 118 outputs a signal to the switch 119 and controls the on/off

of switch 119.

[0183] When receiving a signal from the comparator 118, the switch 119 is turned off to disconnect the LPF 126 from the differential amplifier 127. During the period when no signals are received by the comparator 118, the switch 119 is turned on to connect the LPF 126 with the differential amplifier 127.

[0184] Next, functions and advantageous effects of the fifteenth embodiment will be described.

[0185] The optical add/drop apparatus having the above configuration can keep the operating point stable even if the input light does not exist during the period when the wavelength of light exit from the LD bank 110 is changed in the optical addition circuit 107a, for example, during the period when laser light of wavelength L2 is switched to laser light of wavelength L4.

[0186] This will be explained below in the case where the wavelength L2 is switched to the wavelength L4.

[0187] At first, since a wavelength-division multiplexed signal transmitting through the optical transmission line has an available wavelength L2, the LD bank 110 exits light of the wavelength L2. The exit light is modulated by the MZ modulator 113, added in the QADM102 as an addition light via the N x 1 optical multi/demultiplexer 106, and inputted to the optical transmission line. The exit light is also entered to the operating point control circuit, where it is used to control the operating point of the MZ modulator 113. The exit light is also photoelectrically converted by the PD 116, and an output signal of the PD 116 is judged as to whether it is smaller than or equal to the reference voltage Vref by the comparator 118. That is, whether the intensity of the light of the wavelength L2 exit from the LD bank 110 is a predetermined value or less can be judged by the comparator 118 as to whether the electrical signal that is outputted from the PD 116 is smaller than or equal to the predetermined reference voltage Vref.

[0188] Since the light of the wavelength L2 exit from the LD bank 110 is used as addition light, its light intensity is larger than the predetermined value and hence the comparator 118 does not output any signals. Therefore, the switch 119 is kept on and LPF 126 is kept connected with differential amplifier 127. As a result, the operating point control circuit continues to operate normally.

[0189] Then, the available wavelength of a wavelength-division multiplexed signal transmitting through the optical transmission line is changed from L2 to L4, whereupon the LD bank 110 stops exiting the light of the wavelength L2.

[0190] At this time, the level of the output signal of the PD 116 decreases to approximately zero. Since the output signal is smaller than the reference voltage Vref, the comparator 118 sends a signal to the switch 119. The switch 119 is turned off and the LPF 126 is disconnected from the differential amplifier 127. As a result, the operating point control circuit stops operating, and the operating point is put back to the initial state and kept in a range where it can be controlled by the operating point control circuit. Therefore, the operating point is never left in an unstable state.

[0191] Then, the LD bank 110 exits light of the wavelength L4. At this time, the output signal of the PD 116 increases to approximately the same level as in the case of the wavelength L2. Therefore, the output signal of the PD 116 becomes larger than the reference voltage Vref and hence the comparator 118 does not send any signals. The switch 119 is turned on and the LPF 126 is connected to the differential amplifier 127. At this time, the operating point control circuit controls the operating point starting from the initial state and hence can operate normally.

[0192] While the above description is directed to the case where the LD bank 110 stops the light to exit temporally to change the wavelength of exit light, the operating point can be kept stable in a similar manner also in a case where the light exiting is stopped to use another optical addition circuit 107a in the optical add/drop apparatus.

[0193] Next, the sixteenth embodiment will be described.

[0194] At first, the sixteenth embodiment will be described starting from its configuration.

[0195] As shown in FIG. 16, this optical add/drop apparatus is composed of optical amplifiers 101 and 103, an OADM 102, an 1 x M optical coupler 104, M optical wavelength branching circuits 105, an N x 1 optical multi/demultiplexer 106, and N optical addition circuits 107b.

[0196] Although this optical add/drop apparatus has the M optical wavelength branching circuits 105 and the N optical addition circuits 107b, in FIG. 16 only one of the M optical wavelength branching circuits 105 and only one of the N optical addition circuits 107b are shown by solid lines and the other circuits are shown with broken lines because the circuits of each group have the same configuration.

[0197] A wavelength-division multiplexed optical signal transmitting through an optical transmission line enters the optical add/drop apparatus and is entered to the QADM 102 via the optical amplifier 101. Signal light beams of predetermined wavelengths that have been dropped by the OADM 102 are distributed by the 1 x M optical coupler 104 and then entered to the optical wavelength branching circuits 105, where they are received. On the other hand, WDM optical signals to be added in the OADM 102 are generated by the optical addition circuits 107b, which are provided in N, that is, the number of WDM optical signals to be added in the OADM 102. The optical signals to be added and an optical signal that has not been dropped in the OADM 102 are wavelength-division multiplexed with each other, and a resulting WDM optical signal is outputted to the optical transmission line via the optical amplifier 103.

[0198] Each optical addition circuit 107b is composed of an LD bank 110, optical amplifiers 111 and 115, an optical coupler 140, an MZ modulator 113, PDs 123 and 141, a buffer amplifier 124, amplifiers 121 and 142, a comparator 143, switches 144 and 148, a variable gain amplifier 120, a coupling capacitor 122, a multiplier 125, an LPF 126, a differential amplifier 127, an inductor 128, capacitors 129 and 151, resistors 130, 145, and 146, a low-frequency oscillator 131, field-effect transistors (hereinafter abbreviated as "FETs") 147 and 149, and operational amplifiers 150 and 152.

[0199] In FIG. 16, laser light exit from the LD bank 110 is entered to the MZ modulator 113 via the optical amplifier 111.

[0200] A modulation signal and a low-frequency signal of a predetermined frequency f0 that is outputted from the low-frequency oscillator 131 are inputted to the variable gain amplifier 120. An output signal of the variable gain amplifier 120 is inputted to one modulation-input terminal of the MZ modulator 113 via the amplifier 121 and the coupling capacitor 122.

[0201] As for the other modulation-input terminal of the MZ modulator 113, to which the resistor 130 and a bias T circuit that is composed of the inductor 128 and the capacitor 129 are connected.

[0202] The MZ modulator 113 modulates the light of the LD bank, for example, a wavelength of L2, with the signal supplied from the drive circuit, into an optical signal, and outputs it.

[0203] The output light of the MZ modulator 113 is branched into three beams by the optical coupler 140. First branched output light is entered to the PD 123. Second branched output light is entered to the PD 141. Third branched output light is entered to the abovementioned N x 1 optical multi/demultiplexer 106 via the optical amplifier 115. The first branched output light is detected by the PD 123, and a detection signal is inputted to the multiplier 125 via the buffer amplifier 124. The low-frequency signal that is outputted from the low-frequency oscillator 131 is also inputted to the multiplier 125. The multiplier 125 compares the phases of the input signal supplied from the buffer amplifier 124 and the low-frequency signal supplied from the low-frequency oscillator 131, and outputs a signal in accordance with a phase difference.

[0204] The output signal of the multiplier 125 is inputted to the LPF 126. An output of the LPF 126 is inputted to one input terminal of the differential amplifier 127 via the switch 144 as well as to the non-inverting input terminal (+) of the operational amplifier 152. The other input terminal of the differential amplifier 127 is grounded. An output of the differential amplifier 127 is inputted to the inductor 128 of the bias T circuit, and the bias value is variably controlled so as to correct the operating point.

[0205] An output of the operational amplifier 152 is inputted to the drain terminal of the FET 147 and the source terminal of the FET 149.

[0206] The gate terminal of the FET 147, which is controlled by the switch 148, is connected to a voltage source Vcc via the switch 148. The source terminal of the FET 147 is connected to the inverting input terminal (-) of the operational amplifier 152 via the resistor 145 as well as to the inverting input terminal (-) of the operational amplifier 150 via the resistor 146.

[0207] The gate terminal of the FET 149, which is controlled by the switch 148, is connected to the voltage source Vcc via the switch 148. The drain terminal of the FET 149 is grounded via the capacitor 151 and connected to the non-inverting terminal (+) of the operational amplifier 150.

[0208] A circuit composed of the operational amplifiers 150 and 152, the FETS 147 and 149, the resistors 145 and 146, and the capacitor 151 is a holding circuit for holding the output voltage of the LPF 126.

[0209] On the other hand, the second branched output light is detected by the PD 141, which outputs an electrical signal that is in proportion to the average intensity of the second branched output light. That is, the PD 141 detects the intensity of the light that is exit from the LD bank 110 by monitoring the output light of the MZ modulator 113.

[0210] The electrical signal that is outputted from the PD 141 is amplified by the amplifier 142 and then compared with a reference voltage Vref by the comparator 143. When the electrical signal is smaller than or equal to the reference voltage Vref, the comparator 143 outputs a signal to the switches 144 and 148 and thereby controls these switches.

[0211] The switch 144 can switch connecting the LPF 126 to the differential amplifier 127 and connecting the output terminal of the operational amplifier 150 to the differential amplifier 127. Usually, the switch 144 connects the LPF 126 to the differential amplifier 127, but upon reception of a signal from the comparator 143, the switch 144 switches to connecting the output terminal of the operational amplifier 150 to the differential amplifier 127. When it no longer receives the signal coming from the comparator 143, the switch 144 again connects the LPF 126 to the differential amplifier 127.

[0212] The switch 148 controls the on/off of the FETs 147 and 149 in accordance with a signal supplied from the comparator 143. That is, while a signal from the comparator 143 is not received, the switch 148 connects the voltage source Vcc to the gate terminal of the FET 149, thereby keeping the FET 149 on and keeping the FET 147 off. On the other hand, upon reception of a signal from the comparator 143, the switch 148 turns off the FET 149 and connects the voltage source Vcc to the gate terminal of the FET 147, thereby turning on the FET 147.

[0213] Next, functions and advantageous effects of the sixteenth embodiment will be described.

[0214] The optical add/drop apparatus having the above configuration can keep the operating point of the MZ modulator 113 stable even if the input light no longer

exists during a period when the wavelength of light exit from the LD bank 110 is changed in the optical addition circuit 107b, for example, during a period laser light of a wavelength L2 is changed to laser light of a wavelength L4.

[0215] This will be explained below in the case when the wavelength L2 is changed to the wavelength L4.

[0216] At first, since a wavelength-division multiplexed signal transmitting through the optical transmission line has an available wavelength L2, the LD bank 110 exits light of the wavelength L2. The exit light is modulated by the MZ modulator 113, added by the OADM 102 as addition light via the N x 1 optical multi/demultiplexer 106, and outputted to the optical transmission line. The exit light is also entered, via the optical modulator 113 etc., to the operating point control circuit, where it is used to control the operating point of the MZ modulator 113. The exit light is photoelectrically converted by the PD 141 via the MZ modulator 113 etc. An output signal of the PD 141 is judged by the comparator 143 as to whether it is smaller than or equal to the reference voltage Vref. That is, whether the intensity of the light of the wavelength L2 exit from the LD bank 110 is a predetermined value or less can be judged by the comparator 143 as to whether the electrical signal that is outputted from the PD 141 is smaller than or equal to the predetermined reference voltage Vref.

[0217] Since the light of the wavelength L2 exit from the LD bank 110 is used as addition light, its light intensity is larger than the predetermined value and hence the comparator 143 does not output any signals. Therefore, the switch 144 keeps connecting the LPF 126 to the differential amplifier 127. As a result, the operating point control circuit continues to operate normally. Further, the switch 148 turns the FETs 147 and 149 on and off, respectively. As a result, the output voltage of the LPF 126 is stored in the capacitor 151.

[0218] Then, the available wavelength of a wavelength-division multiplexed signal transmitting through the optical transmission line is changed from L2 to L4, whereupon the LD bank 110 stops exiting the light of the wavelength L2.

[0219] At this time, the level of the output signal of the PD 141 decreases to approximately zero. Since the output signal is smaller than the reference voltage Vref, the comparator 143 sends a signal to the switches 144 and 148. The switch 144 switches from connecting the LPF 126 to the differential amplifier 127 to connecting the output terminal of the operational amplifier 150 to the differential amplifier 127. Further, the switch 148 turns the FET 147 on and turns the FET 149 off. Therefore, the output voltage of the LPF 126 which is as same as the voltage stored in the capacitor 151 is outputted to the output terminal of the operational amplifier 150. As a result, the differential amplifier 127 maintains the state just before the LD bank 110 stops exiting the light of the wavelength L2. Therefore, the operating point is never in an unstable state.

[0220] Then, the LD bank 110 exits light of the wavelength L4. At this time, the output signal of the PD 141 increases to approximately the same level as in the case of the wavelength L2. Therefore, the output signal of the PD 141 becomes larger than the reference voltage Vref and hence the comparator 143 does not send any signals. The switch 144 switches again from connecting the output terminal of the operational amplifier 150 with the differential amplifier 127 to connecting the LPF 126 with the differential amplifier 127. Therefore, the operating point control circuit controls normally the operating point of the MZ modulator 113 based on the optical signal entered from the optical modulator 113.

[0221] In addition, since the operating point control circuit holds the state just before switching the laser light of the wavelength L2 to the laser light of the wavelength L4, the operating point can be compensated for more quickly than in a case where the control of the operating point is started from the initial state.

[0222] While the above description is directed to the case where the LD bank 110 temporally stops the light to exit to change the wavelength of exit light, the operating point can be kept stable in a similar manner also in a case where the light exiting is stopped to use another optical addition circuit 107b in the optical add/drop apparatus.

[0223] Next, the seventeenth embodiment will be described.

[0224] At first the seventeenth embodiment will be described starting from its configuration.
This optical add/drop apparatus is composed of optical amplifiers 101 and 103, an OADM 102, an 1 x M optical coupler 104, M optical wavelength branching circuits 105, an N x 1 optical multi/demultiplexer 106, and N optical addition circuits 107c.

[0225] Although this optical add/drop apparatus has the M optical wavelength branching circuits 105 and the N optical addition circuits 107a, in FIG. 17 only one of the M optical wavelength branching circuits 105 and only one of the N optical addition circuits 107c are shown by solid lines and the other circuits are shown with broken lines because the circuits of each group have the same configuration.

[0226] A wavelength-division multiplexed optical signal transmitting through an optical transmission line enters the optical add/drop apparatus, and is amplified by the amplifier 101 and then entered to the OADM 102. Signal light beams of predetermined wavelengths that have been dropped by the OADM 102 are entered to the 1 x M optical coupler 104. The optical signal(s) distributed by the 1 x M optical coupler 104 are entered to the optical wavelength branching circuits 105, where they are subjected to receiving operations. On the other hand, optical signals to be added by the OADM 102 are generated by the optical addition circuits 107c. The optical signals to be added and an optical signal that has not been dropped in the OADM 102 are wavelength-

division multiplexed with each other, and is amplified by the optical amplifier 103 and then utputted to the optical transmission line.

[0227] Each optical addition circuit 107c is composed of an LD bank 110, optical amplifiers 111 and 115, an optical coupler 114, an MZ modulator 113, a PD 123, a diode 160, amplifiers 121 and 162, a buffer amplifier 124, a comparator 163, a switch 164, a variable gain amplifier 120, a coupling capacitor 122, a multiplier 125, an LPF 126, a differential amplifier 127, an inductor 128, a capacitor 129, resistors 130 and 161, and a low-frequency oscillator 131.

[0228] In FIG. 17, laser light exit from the LD bank 110 is entered to the MZ modulator 113 via the optical amplifier 111.

[0229] A modulation signal and a low-frequency signal of a predetermined frequency f0 that is outputted from the low-frequency oscillator 131 are inputted to the variable gain amplifier 120. An output signal of the variable gain amplifier 120 is inputted to one modulation-input terminal of the MZ modulator 113 via the amplifier 121 and the coupling capacitor 122.

[0230] The resistor 130 and a bias T circuit that is composed of the inductor 128 and the capacitor 129 are connected to the other modulation-input terminal of the MZ modulator 113.

[0231] The MZ modulator 113 modulates the light of the wavelength L2 that is exit from the LD bank 110 into an optical signal with the signal supplied from the drive circuit and outputs it.

[0232] Part of the output light of the MZ modulator 113 is branched off by the optical coupler 114 and thereby taken out. The other part of the output light is entered to the above-mentioned N x 1 optical multi/demultiplexer 106 via the optical amplifier 115. The branched part of the output light is detected by the PD 123, and a detection signal is inputted to the multiplier 125 via the buffer amplifier 124. The low-frequency signal that is outputted from the low-frequency oscillator 131 is also inputted to the multiplier 125. The multiplier 125 compares the phases of the input signal supplied from the buffer amplifier 124 and the low-frequency signal supplied from the low-frequency oscillator 131, and outputs a signal in accordance with a phase difference.

[0233] The output signal of the multiplier 125 is inputted to one input terminal of the differential amplifier 127 via the LPF 126 and the switch 164. The other input terminal of the differential amplifier 127 is grounded. An output of the differential amplifier 127 is inputted to the inductor 128 of the bias T circuit, and the bias value is variably controlled so as to correct the operating point.

[0234] On the other hand, the modulation signal is connected to one terminal of the diode 160. The other terminal of the diode 160 is grounded via the resistor 161. The modulation signal is half-wave-rectified by the diode 160, whereby a voltage corresponding to the intensity of the modulation signal is detected at both ends of the resistor 161.

[0235] The voltage corresponding to the intensity of the modulation signal is amplified by the amplifier 162 and then compared with a reference voltage Vref by the comparator 163. If this voltage is smaller than or equal to the reference voltage Vref, the comparator 163 outputs a signal to the switch 164 and controls it.

[0236] The switch 164 can switch between connecting the LPF 126 to the differential amplifier 127 and connecting a reference voltage V1 to the differential amplifier 127. Normally, the switch 164 connects the LPF 126 to the differential amplifier 127. Upon reception of a signal from the comparator 163, the switch 164 switched to connecting the reference voltage V1 to the differential amplifier 127. When the signal coming from the comparator 163 is terminated, the switch 164 again connects the LPF 126 to the differential amplifier 127.

[0237] The reference voltage V1 has a value in a range where the operating point can be controlled by the operating point control circuit.

[0238] Next, functions and advantageous effects of the seventeenth embodiment will be described.

[0239] The optical add/drop apparatus having the above configuration can keep the operating point stable even during a period when there is no modulation signal to be transmitted in the optical addition circuit 107c.

[0240] For example, the optical addition circuit 107c operates in the following manner in a case where a modulation signal first exists, then loses its existence, and back in existence again.

[0241] At first, a modulation signal to be transmitted modulates input light that is supplied from the LD bank 110 with the MZ modulator 113. Modulated input light as addition light is added as addition light by the OADM 102 supplied via the N x 1 optical multi/demultiplexer 106 and outputted to the optical transmission line.

[0242] The signal intensity of the modulation light is detected by the diode 160 and the resistor 161, and the comparator 163 judges whether a voltage corresponding to the intensity of the modulation signal is smaller than or equal to the predetermined reference voltage Vref. That is, it is judged whether the intensity of the modulation signal is the predetermined value or less.

[0243] At this point, since there exists a modulation signal to be transmitted, the comparator 163 does not send any signals to the switch 164. Therefore, the switch 164 connects the LPF 126 to the differential amplifier 127. The operation point control circuit operates normally, whereby the operating point of the MZ modulator 113 can be controlled by an optical signal entered from the MZ modulator 113.

[0244] Then, since the signal to be added does not exist in the optical add/drop apparatus, or an optical addition circuit of the N number of circuits other than the current optical addition circuit 107c is used, the modulation signal will no longer exist.

[0245] At this time, the voltage value of the resistor 161 decreases to approximately zero. Since the voltage value is smaller than the reference voltage Vref, the

comparator 163 sends a signal to the switch 164. The switch 164 switches from connecting th LPF 126 to the differential amplifier 127 to connecting the reference voltage V1 to the differential amplifier 127. As a result, the operating point control circuit maintains the operating point at the reference voltage V1. Therefore, the operating point is never in an unstable state.

[0246] Then, a modulation signal to be transmitted generates again, whereupon a voltage is developed in the resistor 161. As a result, since the voltage value becomes larger than the reference voltage Vref, the comparator 163 does not send any signals. The switch 164 switches connecting the reference voltage V1 to the differential amplifier 127 to connecting the LPF 126 to the differential amplifier 127. Therefore, the operating point control circuit controls normally the operating point of the MZ modulator 113 based on an optical signal entered from the MZ modulator 113, shifting from the state of the reference voltage V1.

[0247] In this case, if the reference voltage V1 is selected properly in consideration of the temperature of the MZ modulator 113 in operation and other factors, the operating point can be compensated more quickly than in the case of starting the operating point control from the initial state.

[0248] Next, the eighteenth embodiment will be described.

[0249] At first, the eighteenth embodiment will be described starting from its configuration.

[0250] In FIG. 18, this optical add/drop apparatus is composed of optical amplifiers 101 and 103, an OADM 102, an 1 x M optical coupler 104, M optical wavelength branching circuits 105, an N x 1 optical multi/demultiplexer 106, and N optical addition circuits 107d.

[0251] Although this optical add/drop apparatus has the M optical wavelength branching circuits 105 and the N optical addition circuits 107d, in FIG. 18 only one of the M optical wavelength branching circuits 105 and only one of the N optical addition circuits 107d are shown by solid lines and the other circuits are shown with broken lines because the circuits of each group have the same configuration.

[0252] A wavelength-division multiplexed optical signal transmitting through an optical transmission line enters the optical add/drop apparatus, is amplified by the amplifier 101, and then entered to the OADM 102. Signal light beams of predetermined wavelengths that have been dropped by the OADM 102 are entered to the 1 x M optical coupler 104. The optical signal(s) distributed by the 1 x M optical coupler 104 are entered to the optical wavelength branching circuits 105, where they are subjected to receiving operations. On the other hand, optical signals to be added in the OADM 102 are generated by the optical addition circuits 107d. The optical signals to be added and an optical signal that has not been dropped in the OADM 102 are wavelength-division multiplexed with each other, and a resulting optical signal is amplified by the optical amplifi r 103 and then outputted to the optical transmission line.

[0253] Each optical addition circuit 107d is composed of an LD bank 110, optical amplifiers 111 and 115, optical couplers 112 and 114, an MZ modulator 113, PDs 116 and 123, amplifiers 117, 121, and 162, a buffer amplifier 124, comparators 118 and 163, a switch 119, a variable gain amplifier 120, a coupling capacitor 122, a multiplier 125, an LPF 126, a differential amplifier 127, an inductor 128, a capacitor 129, resistors 130 and 161, a low-frequency oscillator 131, a diode 160, an adder 170, and an optical attenuator 171.

[0254] In FIG. 18, laser light exit from the LD bank 110 is entered to the optical amplifier 111. Amplified light is branched into two beams by the optical coupler 112, and first branched light is entered to the MZ modulator 113 via the optical attenuator 171.

[0255] On the other hand, second branched light that has been branched off by the optical coupler 112 is entered to the PD 116. An electrical signal that is outputted from the PD 116 is amplified by the amplifier 117 and then compared with a reference voltage Vref1 by the comparator 118. When the electrical signal is smaller than or equal to the reference voltage Vref1, the comparator 118 outputs a signal to the switch 119 and the adder 170. The switch 119 is controlled in accordance with the output of the comparator 118. When receiving a signal from the comparator 118, the switch 119 is turned off and thereby disconnects the LPF 126 from the differential amplifier 127. During a period when no signal is received from the comparator 118, the switch 119 is kept on and thereby connects the LPF 126 to the differential amplifier 127.

[0256] A modulation signal and a low-frequency signal of a predetermined frequency f0 that is outputted from the low-frequency oscillator 131 are inputted to the variable gain amplifier 120. An output signal of the variable gain amplifier 120 is inputted to one modulation-input terminal of the MZ modulator 113 via the amplifier 121 and the coupling capacitor 122.

[0257] The resistor 130 and a bias T circuit that is composed of the inductor 128 and the capacitor 129 are connected to the other modulation-input terminal of the MZ modulator 113.

[0258] The MZ modulator 113 modulates light that is exited from the LD bank 110, for example, the light of a wavelength L2 into an optical signal, with the signal supplied from the drive circuit, and outputs it.

[0259] Part of the output light of the MZ modulator 113 is branched off by the optical coupler 114 and thereby taken out. The other part of the output light is entered to the above-mentioned N x 1 optical multi/demultiplexer 106 via the optical amplifier 115. The branched part of the output light is detected by the PD 123, and a detected signal is inputted to the multiplier 125 via the buffer amplifier 124. The low-frequency signal that is outputted from the low-frequency oscillator 131 is also inputted to the multiplier 125. The multiplier 125 compares the phases of the input signal supplied

from the buffer amplifier 124 and the low-frequency signal supplied from the low-frequency oscillator 131, and outputs a signal in accordance with a phase difference.

[0260] The output signal of the multiplier 125 is inputted to one input terminal of the differential amplifier 127 via the LPF 126 and the switch 119. The other input terminal of the differential amplifier 127 is grounded. An output of the differential amplifier 127 is inputted to the inductor 128 of the bias T circuit, and the bias value is variably controlled so as to correct the operating point of the MZ modulator 113.

[0261] On the other hand, the modulation signal is grounded via the diode 160 and the resistor 161. A voltage corresponding to the intensity of the modulation signal is detected at both terminals of the resistor 161.

[0262] The voltage corresponding to the intensity of the modulation signal is inputted, via the amplifier 162, to the comparator 163, where it is compared with a reference voltage Vref2. If an electrical signal is smaller than or equal to the reference voltage Vref2, the comparator 163 outputs a signal to the adder 170.

[0263] The adder 170 ANDs the signal supplied from the comparator 118 and the signal supplied from the comparator 163 and outputs a result to the optical attenuator 171. That is, the adder 170 outputs a signal to the optical attenuator 171 when receiving (a) signal(s) from either or both comparators 118 and 163, and only when no signals are received from either of the comparators 118 and 163 does it not output any signals to the optical attenuator 171.

[0264] When receiving an output of the adder 170, the optical attenuator 171 attenuates the intensity of the input light that is supplied from the optical coupler 112 to a predetermined intensity. When receiving no output from the adder 170, the optical attenuator 171 trajects the input light that is supplied from the optical coupler 112 and outputs it to the MZ modulator 113.

[0265] Next, functions and advantageous effects of the eighteenth embodiment will be described.

[0266] The optical add/drop apparatus having the above configuration can keep the operating point stable even if the input light loses its existence during a period when the wavelength of light exit from the LD bank 110 is changed in the optical addition circuit 107d, for example, during a period when laser light of a wavelength L2 is changed to laser light of a wavelength L4. Further, neither ASE nor input light that is not modulated with a modulation signal is sent to the N x 1 optical multi/demultiplexer 106 even during a period when the optical addition circuit 107d has no modulation signal to be transmitted or there is no light to be exited from the LD bank 110.

[0267] The operation of the operating point control circuit in the fourth embodiment to stabilize the operating point is the same as that in the first embodiment and hence is not described here.

[0268] The operation in the fourth embodiment to avoid sending ASE or input light that is not modulated with a modulation signal to the N x 1 optical multi/demultiplexer 106 will be described below.

[0269] The intensity of a modulation signal is detected by the diode 160 and the resistor 161. A voltage corresponding to the intensity of the modulation signal is judged by the comparator 163 as to whether the voltage is smaller than or equal to the predetermined reference voltage Vref2, that is, whether the intensity of the modulation signal is the predetermined value or less.

[0270] When there exists a modulation signal to be transmitted, the comparator 163 does not send any signals to the adder 170. Therefore, the adder 170 does not output any signals to the optical attenuator 171, and hence the MZ modulator 113 modulates the light received with the modulation signal and outputs resulting light.

[0271] On the other hand, when the modulation signal no longer exists, the voltage value of the resistor 161 decreases to approximately zero. Since the voltage value becomes smaller than or equal to the reference voltage Vref2, the comparator 163 sends a signal to the adder 170. Therefore, the adder 170 outputs a signal to the optical attenuator 171, which attenuates the input light to the predetermined light intensity (including zero). Therefore, neither ASE nor input that is not modulated with a modulation signal is sent to the N x 1 optical multi/demultiplexer 106.

[0272] The input light exit from the LD bank 110 is photoelectrically converted by the PD 116. The comparator 118 judges whether an output signal of the PD 116 is smaller than or equal to the reference voltage Vref1. That is, whether or not input light is being exit from the LD bank 110 can be judged by the comparator 118 as to whether the electrical signal that is outputted from the PD 116 is smaller than or equal to the predetermined reference voltage Vref1.

[0273] When the LD bank 110 is exiting input light, the light intensity is larger than the predetermined value and hence the comparator 118 does not send any signals to the adder 170. Therefore, the adder 170 does not output any signals to the optical attenuator 171, and hence the MZ modulator 113 modulates the light received with a modulation signal and outputs it.

[0274] On the other hand, when the LD bank 110 stops exiting input light, the output signal of the PD 116 decreases to approximately zero. Since the output signal becomes smaller than or equal to the reference voltage Vref1, the comparator 118 sends a signal to the adder 170. Therefore, the adder 170 outputs a signal to the optical attenuator 171, which attenuates ASE that is generated in the optical amplifier 111 etc. to the predetermined light intensity (including zero). Therefore, ASE is not sent to the N x 1 optical multi/demultiplexer 106.

[0275] Naturally, when neither a modulation signal nor input light exists, the adder 170 outputs a signal to the optical attenuator 171 and hence ASE is not sent to the N x 1 optical multi/demultiplexer 106.

[0276] Next, the nineteenth embodiment will be described.

[0277] At first, the nineteenth embodiment will be described starting from its configuration.

[0278] In FIG. 19, this optical add/drop apparatus is composed of optical amplifiers 101 and 103, an OADM 102, an 1 x M optical coupler 104, M optical wavelength branching circuits 105, an N x 1 optical multi/demultiplexer 106, and N optical addition circuits 107e.

[0279] Although this optical add/drop apparatus has the M optical wavelength branching circuits 105 and the N optical addition circuits 107e, in FIG. 19 only one of the M optical wavelength branching circuits 105 and only one of the N optical addition circuits 107e are shown by solid lines and the other circuits are shown with broken lines because the circuits of each group have the same configuration.

[0280] A wavelength-division multiplexed optical signal transmitting an optical transmission line enters the optical add/drop apparatus, and is amplified by the amplifier 101 and then entered to the OADM 102. Signal light beams of predetermined wavelengths that have been dropped by the OADM 102 are entered to the 1 x M optical coupler 104. The optical signals distributed by the 1 x M optical coupler 104 are entered to the optical wavelength branching circuits 105, where they are subjected to receiving operations. On the other hand, optical signals to be added in the OADM 102 are generated by the optical addition circuits 107e. The optical signals to be added and an optical signal that has not been dropped in the OADM 102 are wavelength-division multiplexed with each other, and a resulting optical signal is amplified by the optical amplifier 103 and then outputted to the optical transmission line.

[0281] Each optical addition circuit 107e is composed of an LD bank 110, optical amplifiers 111 and 115, optical couplers 112 and 114, an MZ modulator 113, PDs 116 and 123, amplifiers 117, 121, and 162, a buffer amplifier 124, comparators 118 and 163, a switch 181, a variable gain amplifier 120, a coupling capacitor 122, a multiplier 125, an LPF 126, a differential amplifier 127, an inductor 128, a capacitor 129, resistors 130 and 161, a low-frequency oscillator 131, a diode 160, and an adder 180.

[0282] In FIG. 19, laser light exit from the LD bank 110 is entered to the optical amplifier 111. Amplified light is branched into two beams by the optical coupler 112, and first branched light is entered to the MZ modulator 113.

[0283] On the other hand, second branched light that has been branched off by the optical coupler 112 is entered to the PD 116. An electrical signal that is outputted from the PD 116 is amplified by the amplifier 117 and then compared with a reference voltage Vref1 by the comparator 118. When the electrical signal is smaller than or equal to the reference voltage Vref1, the comparator 118 outputs a signal to the switch 181 and the adder 180.

[0284] The switch 181 can switch between connecting the LPF 126 to the differential amplifier 127 and connecting a reference voltage V1 to the differential amplifier 127. Normally, the switch 181 connects the LPF 126 to the differential amplifier 127. Upon reception of a signal from the comparator 118, the switch 181 switches to connecting the reference voltage V1 to the differential amplifier 127. When the signal coming from the comparator 118 is terminated, the switch 181 again connects the LPF 126 to the differential amplifier 127.

[0285] The reference voltage V1 has a voltage value in a range where the operating point can be controlled by the operating point control circuit.

[0286] A modulation signal and a low-frequency signal of a predetermined frequency f0 that is outputted from the low-frequency oscillator 131 are inputted to the variable gain amplifier 120. An output signal of the variable gain amplifier 120 is inputted to one modulation-input terminal of the MZ modulator 113 via the amplifier 121 and the coupling capacitor 122.

[0287] The resistor 130 and a bias T circuit that is composed of the inductor 128 and the capacitor 129 are connected to the other modulation-input terminal of the MZ modulator 113.

[0288] The MZ modulator 113 modulates the light of a wavelength L2, for example, that is exit from the LD bank 110 with the signal supplied from the drive circuit, into an optical signal, and outputs it. Further, when receiving a signal from the adder 180, the MZ modulator 113 is prevented from producing output light by shifting the phases of light beams transmitting through two respective optical waveguides in the MZ modulator 113 to form a phase difference of 180°.

[0289] Part of the output light of the MZ modulator 113 is branched off by the optical coupler 114 and thereby taken out. The other part of the output light is entered to the above-mentioned N x 1 optical multi/demultiplexer 106 via the optical amplifier 115. A part of the branched output light is detected by the PD 123, and the detected signal is inputted to the multiplier 125 via the buffer amplifier 124. The low-frequency signal that is outputted from the low-frequency oscillator 131 is also inputted to the multiplier 125. The multiplier 125 compares the phases of the input signal supplied from the buffer amplifier 124 and the low-frequency signal supplied from the low-frequency oscillator 131, and outputs a signal in accordance with a phase difference.

[0290] The output signal of the multiplier 125 is inputted to one input terminal of the differential amplifier 127 via the LPF 126 and the switch 181. The other input terminal of the differential amplifier 127 is grounded. An output of the differential amplifier 127 is inputted to the inductor 128 of the bias T circuit, and the bias value is variably controlled so as to correct the operating point of the MZ modulator 113.

[0291] On the other hand, the modulation signal is grounded via the diode 160 and the resistor 161. A voltage corresponding to the intensity of the modulation sig-

nal is detected at both ends of the resistor 161.

[0292] Th voltage corresponding to the intensity of the modulation signal is inputted, via the amplifier 162, to the comparator 163, where it is compared with a reference voltage Vref2. If this voltage is smaller than or equal to the reference voltage Vref2, the comparator 163 outputs a signal to the adder 180.

[0293] The adder 180 ANDs the outputs of the comparators 118 and 163 and outputs a result to the MZ modulator 113.

[0294] Next, functions and advantageous effects of the nineteenth embodiment will be described.

[0295] The optical add/drop apparatus having the above configuration can keep the operating point stable even if the input light loses its existence during a period when the wavelength of light exit from the LD bank 110 is changed in the optical addition circuit 107e, for example, during a period when laser light of a wavelength L2 is changed to laser light of a wavelength L4. Further, neither ASE nor input light that is not modulated with a modulation signal is outputted to the N x 1 optical multi/demultiplexer 106 even during a period when the optical addition circuit 107e has no modulation signal to be transmitted or there is no light to be exited from the LD bank 110.

[0296] The operation of the operating point control circuit in the fifth embodiment to stabilize the operating point is the same as that in the first embodiment except that, in place of the switch 119 being turned on or off, the switch 164 connects one input terminal of the differential amplifier 127 to the LPF 126 or the terminal of the reference voltage V1, and hence it is not described here.

[0297] The operation in the fifth embodiment to avoid outputting ASE or input light that is not modulated with a modulation signal to the N x 1 optical multi/demultiplexer 106 will be described below.

[0298] The intensity of a modulation signal is detected by the diode 160 and the resistor 161. A voltage corresponding to the intensity of the modulation signal is judged by the comparator 163 as to whether the voltage is smaller than or equal to the predetermined reference voltage Vref2, that is, whether the intensity of the modulation signal is the predetermined value or less.

[0299] When there is a modulation signal to be transmitted, the comparator 163 does not output any signals to the adder 180. Therefore, the adder 180 does not output any signals to the optical modulator 113, and hence the MZ modulator 113 modulates the received light by the modulation signal and outputs it.

[0300] On the other hand, when the modulation signal no longer exists, the voltage value of the resistor 161 decreases to approximately zero. Since the voltage value becomes smaller than or equal to the reference voltage Vref2, the comparator 163 outputs a signal to the adder 180. Therefore, the adder 180 outputs a signal to the optical modulator 113, which shifts the phase differences of respective light beams transmitting through two light waveguides in the MZ modulator 113 by 180°, so the producing of output light is stopped. Therefore, neither ASE nor input that is not modulated with a modulation signal is sent to the N x 1 optical multi/demultiplexer 106.

[0301] The input light exited from the LD bank 110 is photoelectrically converted by the PD 116. The comparator 118 judges whether an output signal of the PD 116 is smaller than or equal to the reference voltage Vref1. That is, whether input light is being exited from the LD bank 110 can be judged by the comparator 118 as to whether the electrical signal that is outputted from the PD 116 is smaller than or equal to the predetermined reference voltage Vref1.

[0302] When the LD bank 110 is exiting input light, the light intensity is larger than the predetermined value and hence the comparator 118 does not output any signals to the adder 180. Therefore, the adder 180 does not output any signals to the optical modulator 113, and hence the MZ modulator 113 modulates the input light with a modulation signal and outputs it.

[0303] On the other hand, when the LD bank 110 is not exiting light, the output signal of the PD 116 decreases to approximately zero. Since the output signal becomes smaller than or equal to the reference voltage Vref1, the comparator 118 outputs a signal to the adder 180. Therefore, the adder 180 outputs a signal to the optical modulator 113, which attenuates ASE that is generated in the optical amplifier 111 and etc. Therefore, ASE is not outputted to the N x 1 optical multi/demultiplexer 106.

[0304] Naturally, when neither a modulation signal nor input light exists, the adder 180 outputs a signal to the optical modulator 113 and hence ASE is not outputted to the N x 1 optical multi/demultiplexer 106.

[0305] The LD bank 110 used in the first to fifth embodiments can be replaced by a tunable wavelength laser capable of exiting light of an arbitrary wavelength.

Claims

1. An optical communication apparatus comprising:

    an optical modulating means for modulating input light in accordance with a modulation signal to be transmitted;

    an optical branching means for branching a modulated optical signal that is exit from said optical modulating means into a first branched optical signal and a second branched optical signal;

    an operating point controlling means for controlling said optical modulating means in accordance with said second branched optical signal exit from said optical branching means; and

    a stabilizing means for controlling said operat-